Computer Networks & Software Inc.

Accelerating CNS

Development and Demonstration of the NASA Small Aircraft Transportation System(SATS) Airborne Internet(AI)

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I-CNS Conference

April 30, 2002

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Agenda

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GLENN RESEARCH CENTER

- **Project Overview**
- **Snapshot of the work performed**
  - **System engineering and analysis tasks**
- **Testbed/demonstration platform**

SATS Program Objectives

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- **Concept: Add mobility and economic grow to communities - by increasing smaller airport capacity**
- **Objectives:**
  - **Higher volume operations in non-radar airspace at non-towered facilities**
  - **Lower landing minimums at minimally equipped landing facilities**
  - **Increase single pilot crew safety mission reliability**
  - **En route procedures and systems for integrated fleet operations**

SATS @ I-CNS

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- **NASA GRC SATS AI Demonstration**
  - **Demonstrations Throughout the Day**
- **SATS Workshop Session on Thursday**

SATS AI Project Summary

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- **Project:**
  - **Develop the requirement, architecture, and system level design baselines,**
  - **and establish the evaluation testbed for the Airborne Internet.**
- **AI Objective:**
  - **Consolidate and integrate the exchange of CNS data.**
  - **Minimize the number of radios and antennas on an aircraft. Goal is to provide common access means for all wireless aircraft applications.**
- **Deliverables(FY01):**
  - **AI Requirements Document**
  - **Technology Evaluation Report**
  - **NAS Infrastructure Assessment**
  - **Preliminary Candidate AI Architecture Report**
  - **Preliminary Candidate AI Architecture Evaluation Report**

CNS Team

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- **Computer Networks & Software, Inc. (CNS) - Prime**
- **Mulkerin Associates Inc. (MAI)**
- **AvCS Research Ltd.**
- **Microflight, Inc.**
- **Project Management Enterprises, Inc. (PMEI)**
- **AvCom, Inc.**
- **Comptel, Inc.**

Airborne Internet Notional Diagram[1]

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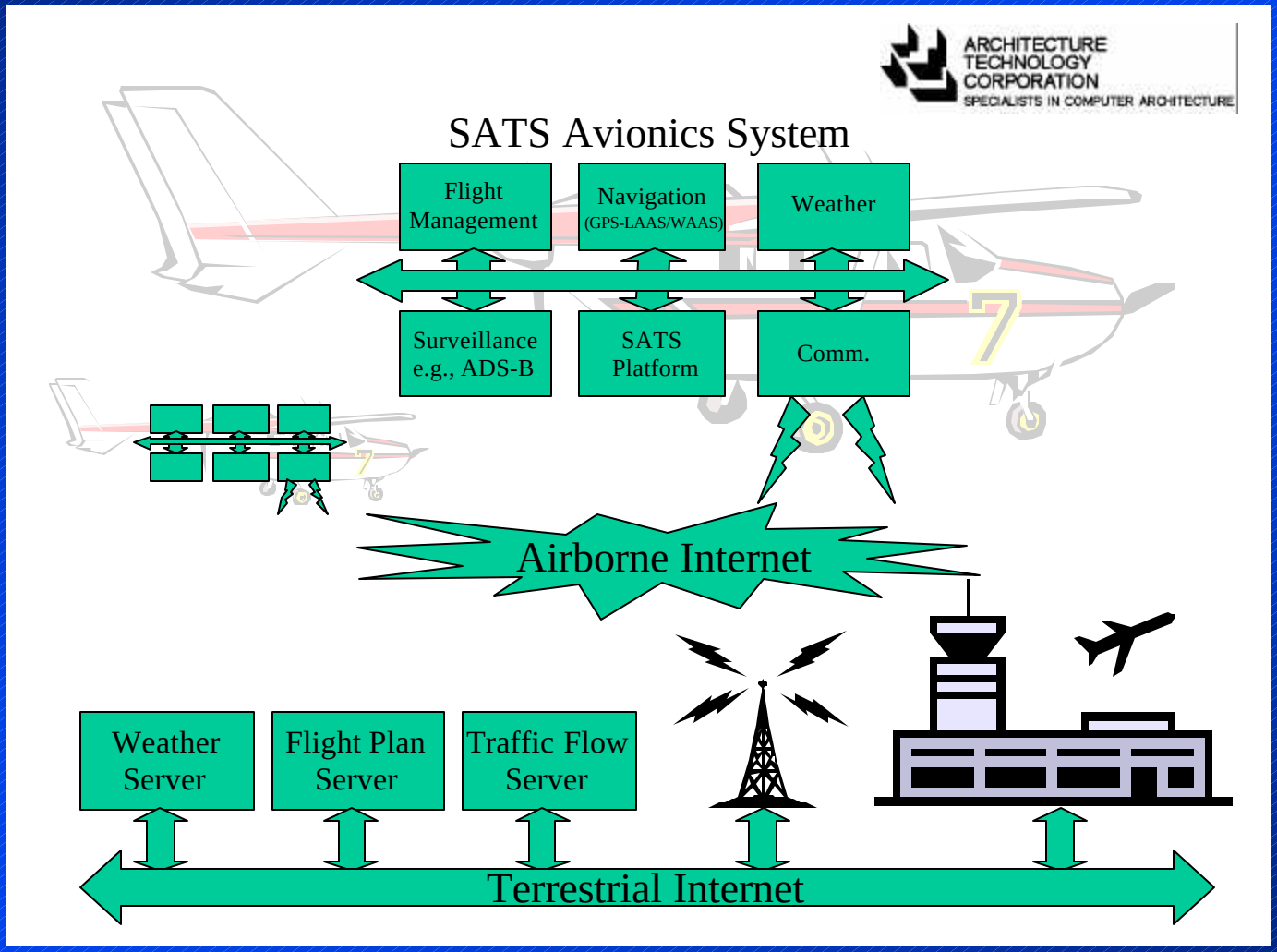

1. Source: SATS Airborne Internet Joint Meeting ATC/CNS, Architecture Technology Corporation Briefing, 3/1/02.

System Engineering Challenge

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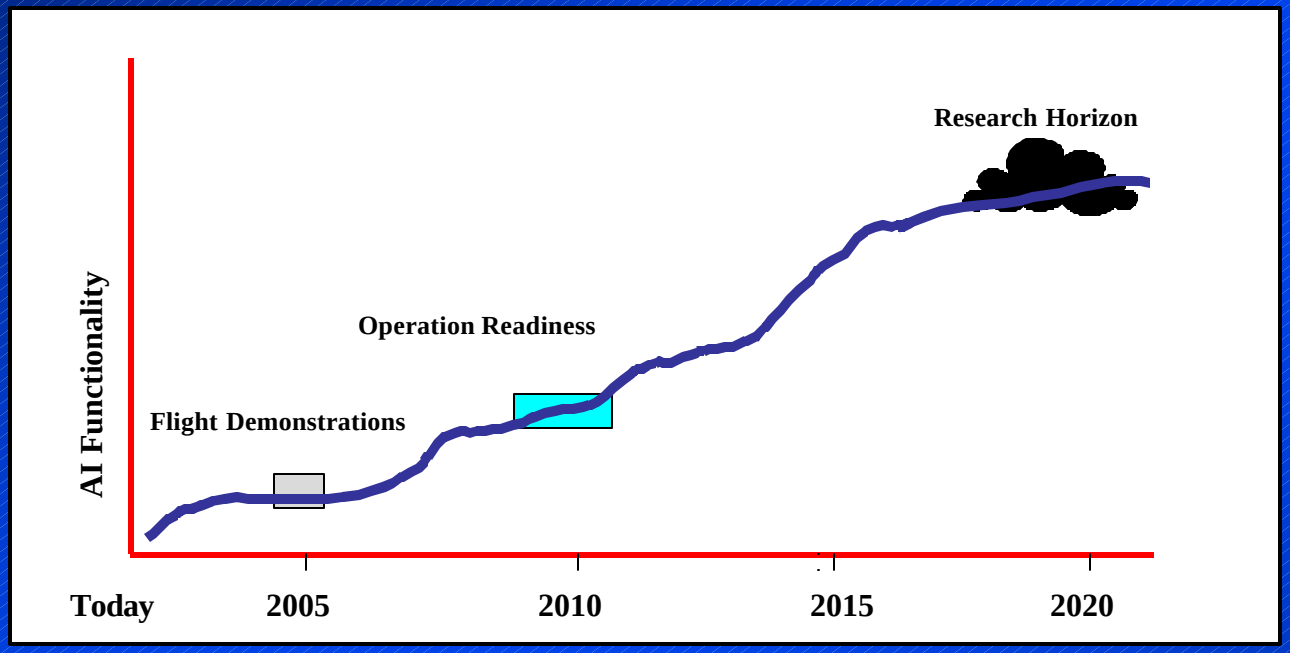

- **Design for reaching horizon – max degrees of freedom**
- **Use an incremental approach – as Concept of Operations evolves**
- **Provide for early demonstrations of concepts**
- **Interoperate with the NAS**
- **Use an Integrated CNS approach**
- **Obtain low cost solutions**

Generic SATS AI Model

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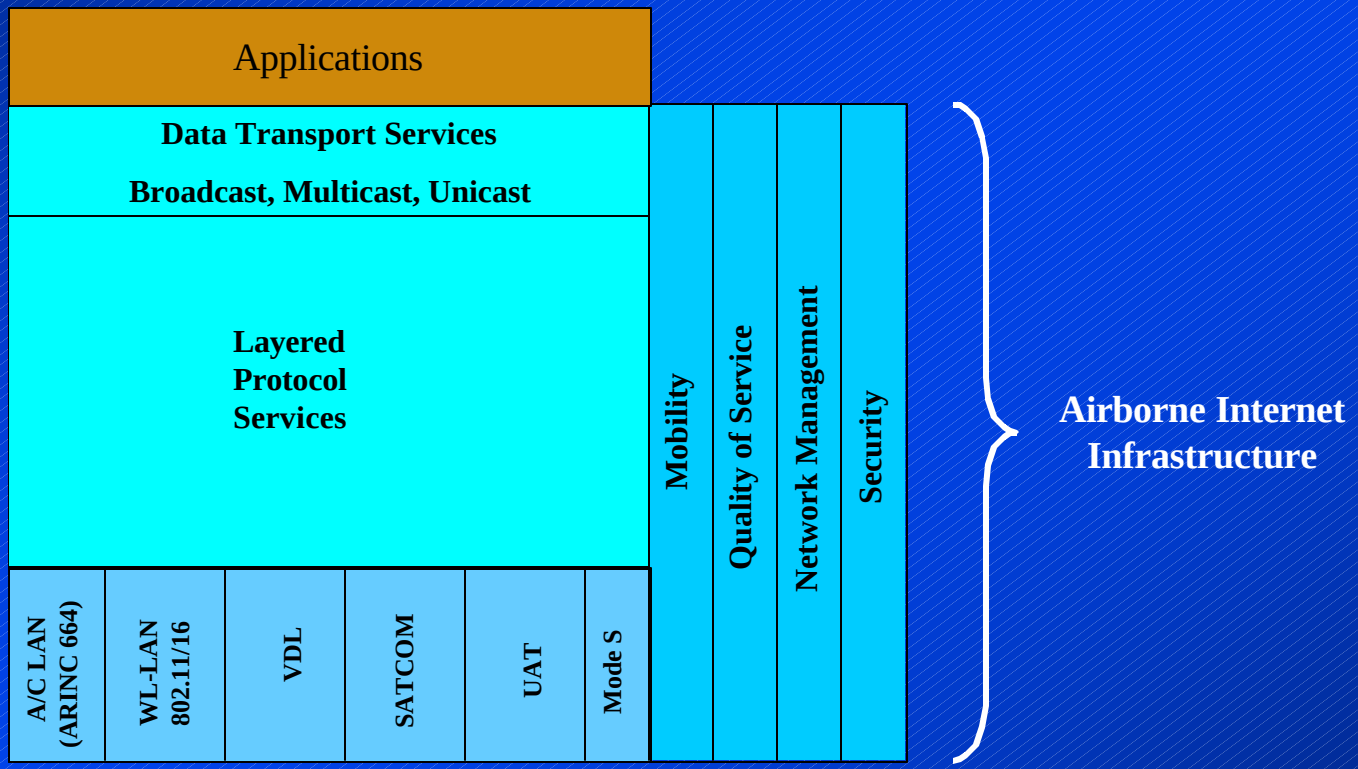

All the similarities to the ATN design challenge of the 1980's

CNS SATS Airborne Internet Environment

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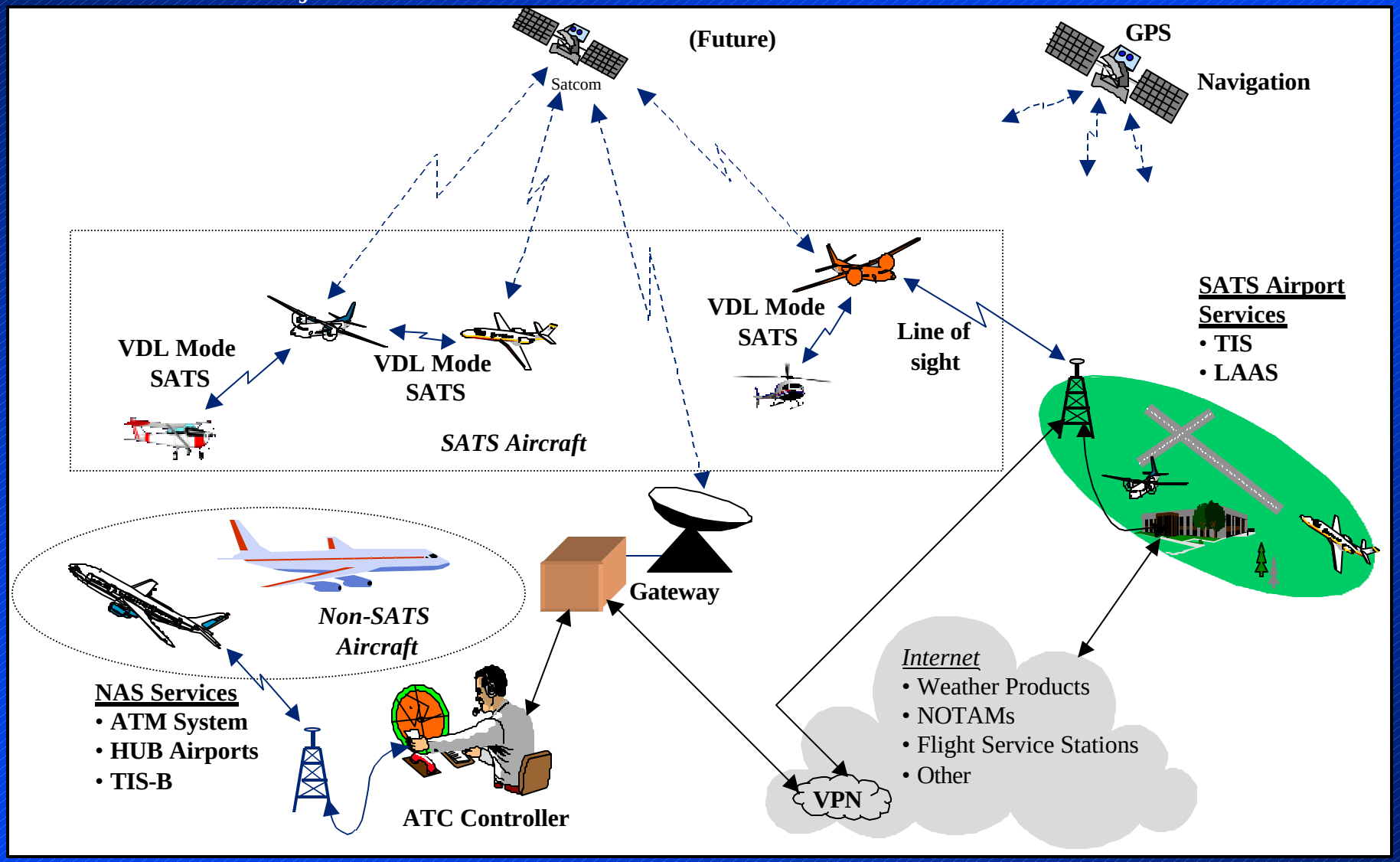

AI Requirements Development Methodology

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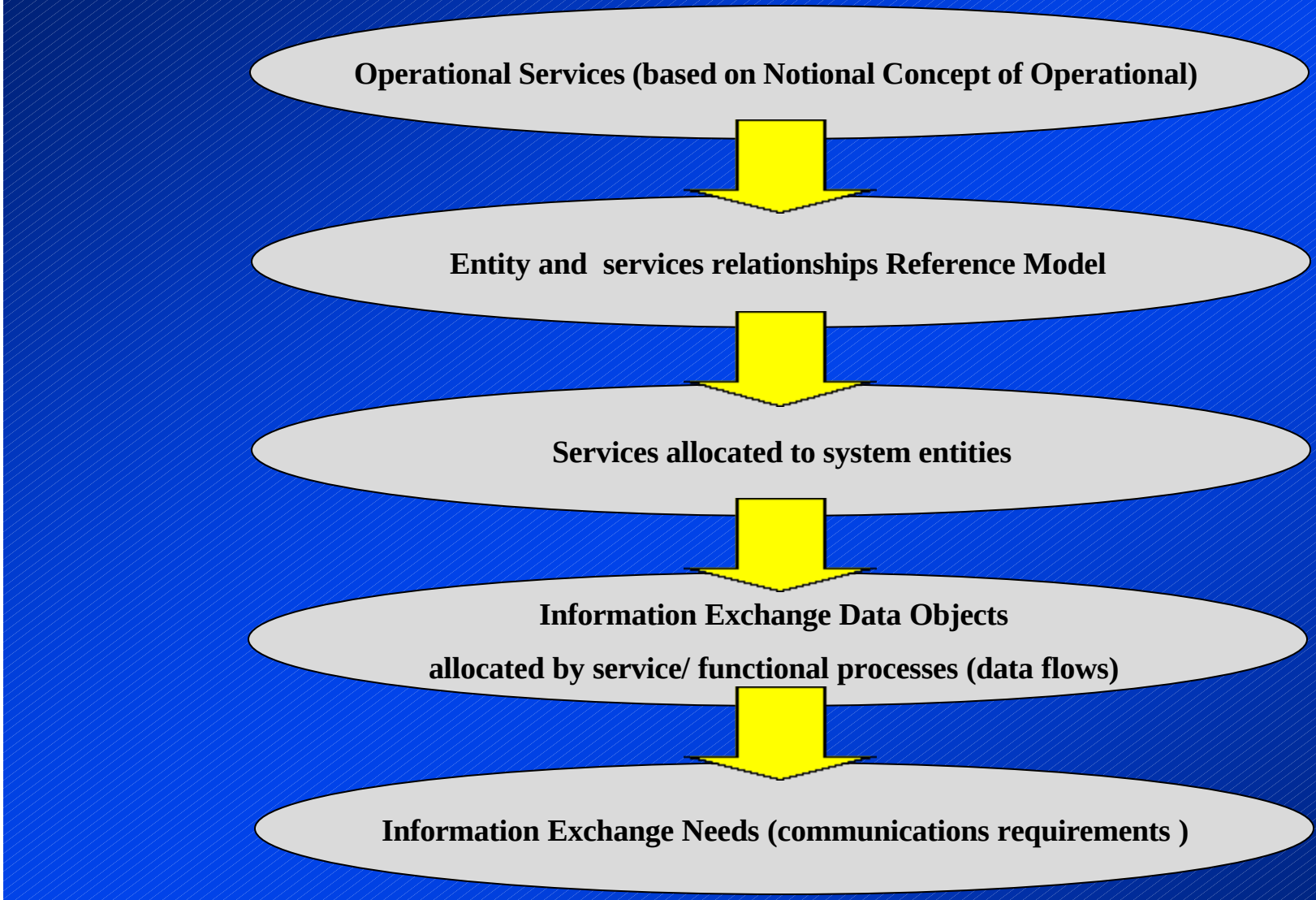

AI Requirements

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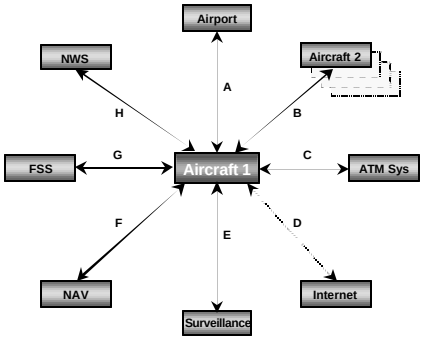
Macro-Level Object Oriented Analysis Process

Operational Services (based on Operational Concepts)

Ref #	SATSUser Services	Functional Capability
1	Flight Service	File flight plans and amendments. Process flight plans and amendments. Provide information for flight plans. Obtain in-flight or pre-flight weather and NAS status (NOTAMs) advisories. *(Near real time and forecast, tactical and strategic)* Obtain in-flight or pre-flight traffic advisories. *(Existing tactical and strategic)* Obtain in-flight NAS status advisories – current and scheduled.
2	Air Traffic Service	Provide separation of aircraft during ground operations. Provide separation of in-flight IFR aircraft. Avoid potential hazards and collisions. Maintain minimum distance from Special Use Airspace (SUA). Monitor flight progress. Enable in-flight sequencing, spacing, and flow management for SATS aircraft. Obtain pre-flight runway, taxi sequence, and movement restrictions. Project aircraft in-flight position and identify potential conflicts. Provide data to support managing use of SUA.
3	Emergency and Alerting Service	Provide emergency assistance and alerts. *(For downed or troubled aircraft)* Support search and rescue.
4	Self-Separation and Sequencing Service	Provide data to ensure proper separation to avoid potential hazards and collisions. Provide data to support VFR and IFR traffic separation. Provide data to monitor flight progress. Provide self-separation in NAS.
5	NavigationService	Provide airborne navigation guidance.
6	Pilot/Aircraft Information Service	Provide information concerning the flight. Enable separation of in-flight IFR aircraft. Enable in-flight sequencing and spacing for SATS aircraft. Provide aircraft in-flight position and identify potential conflicts.
7	Aircraft and Travel Service	Provide information about airport services. Notification to owner/operator about change in aircraft availability. Notification to owner/operator about aircraft maintenance issues. Provide other travel related information.
8	Public Information Exchange Service	Provide in-flight entertainment Provide public communications including email and web browsing.

Entity and services relationships Reference Model



Services allocated to system entities

State	Purpose	Functions	A/C 1	A/C 2	Int	Surv	NAV	FSS	NWS	ATM Sys	Airport
2005	Provide data for tracking aircraft on the ground. Provide data for tracking an aircraft enroute Support safe separation between participating traffic and airspace.	Provide data to ensure proper separation to avoid potential hazards and collisions. Provide data to support VFR and IFR traffic separation. Provide data to monitor flight progress.	X			X					

Information Exchange Data Objects allocated by service/ functional processes (data flows)

State	Purpose	Functions	FPU	WX	AS	MC	NAV	ASI	PE	PIE
2005	Provide data for tracking aircraft on the ground. Provide data for tracking an aircraft enroute Support safe separation between participating traffic and airspace.	Provide data to ensure proper separation to avoid potential hazards and collisions. Provide data to support VFR and IFR traffic separation. Provide data to monitor flight progress.			X					

Information Exchange Needs (communications requirements)

Information Exchange – (IE Object) Airspace Situation (AS) Applicable Interface: (Entity-to-Entity) E	Type: G/A Integrity (Error Rate): High Information Unit Size (Min, Max, Avg): 0.2 Kb, 13 Kb, 11 Kb Frequency of Occurrence: 5 seconds Acceptable Delay: 5 seconds Authentication: No Priority: Medium Retransmission Required: No Suitable for Addressed Communications: No Suitable for Broadcast: Yes Suitable for Multicast: Yes

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SATS Flight Profile

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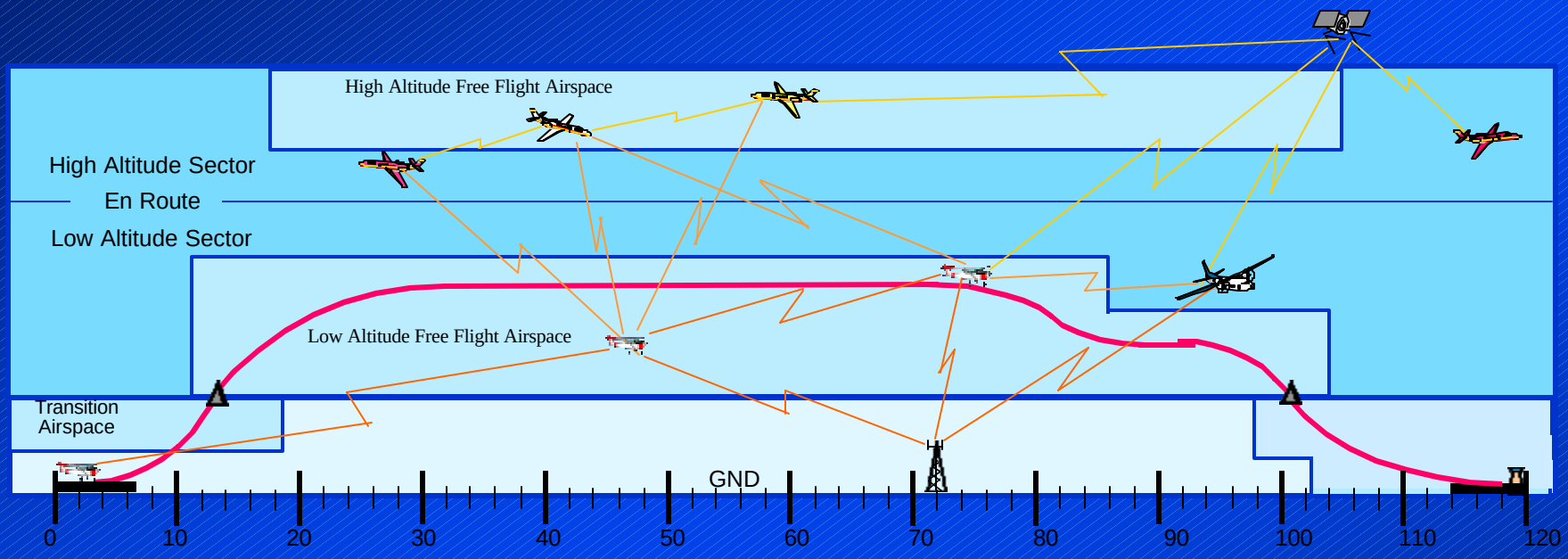

Airborne Internet Air/Ground Messages

	Human	System	Total
Total Load (Kb)	**70**	**30,691**	**30,761**
Average Message Size (Kb)	**1.3**	**4.0**	**4.0**
Average Load/Minute (Kb/min)	**0.6**	**255.8**	**256.3**
Total # Messages	**55**	**7,671**	**7,726**
Average # Messages/Minute	**0.5**	**63.9**	**64.4**

Technology Evaluation

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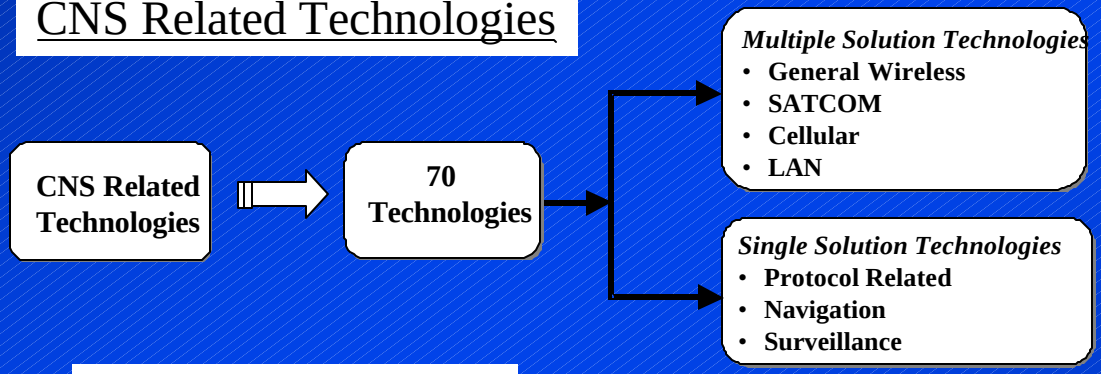
CNS Related Technologies



Architectural Toolkit

Near-term Technologies

Tool Kit	Technologies
1 / Wireless	VDL M2-B, VDL M4, VDL M3, UAT
2 / SATCOM	Inmarsat INM 3 & 4, GlobalStar/ Qualcom
3 / Cellular	3GPP, UMTS, Aircell
4 / LAN	802.11, ARINC 664
5 / Protocols	ATN, IPv4, IPv6, VoIP, IPSec, Mobile IP, QoS, Multicast, Self Organizing MANET, P-P, CDMA, IP Over M2, M3, M4
6 / Navigation	LAAS, WAAS
7 / Surveillance	ADS-B, TIS-B, TIS

Technologies to be Researched

Tool Kit	Technology	Comments
Wireless	VDL Mode 4 - Like	Wider bandwidth
SATCOM	Packet Mode - C Band	Wider bandwidth
	K Band	Weight, size, and power
	Motient	Collect Information
	Inmarsat 3 & 4 - MPDS	Collect Information
Cellular	UMTS for ATC	U.S. ATC suitability

SATS Technology & Architecture Relationship

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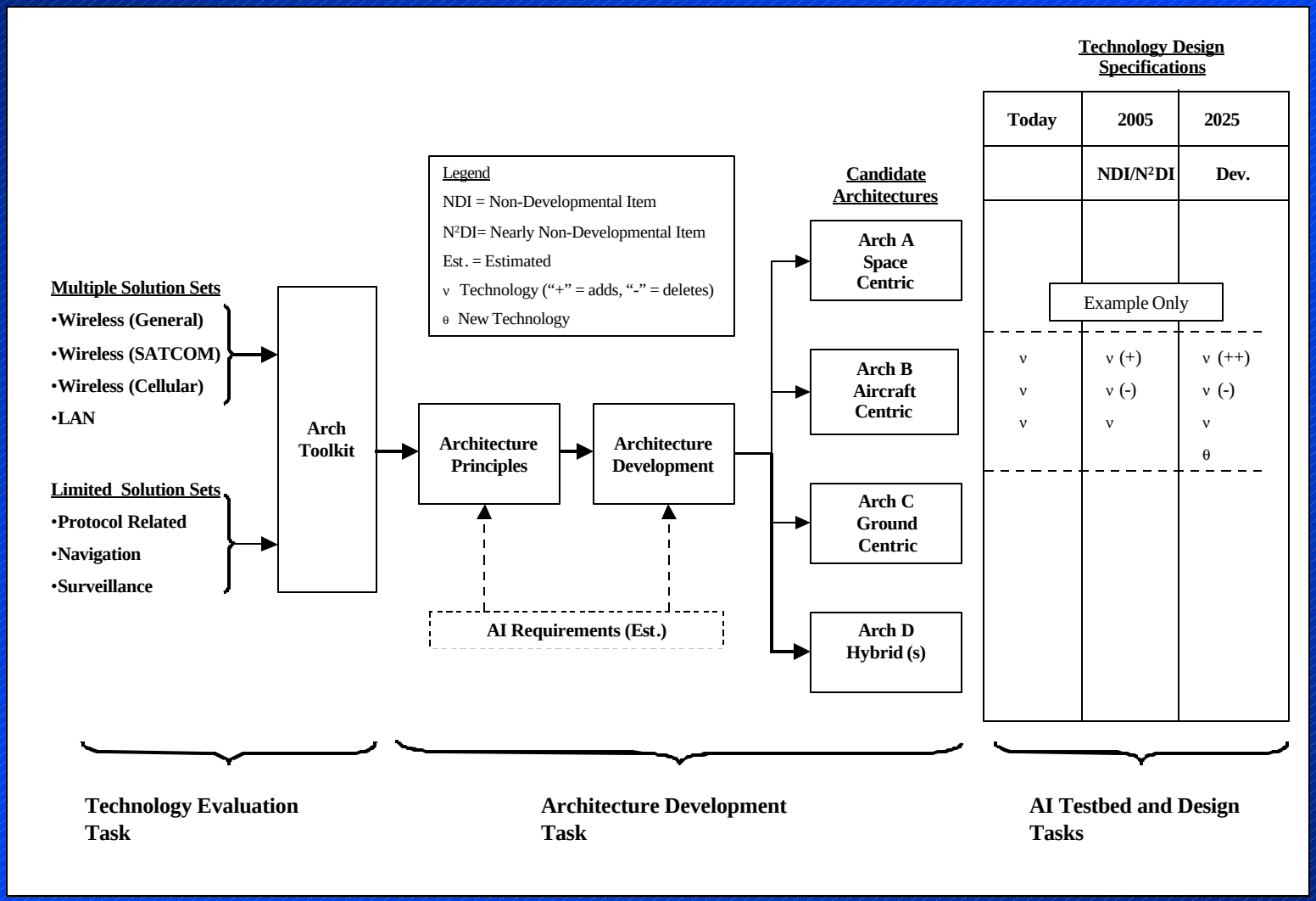

Common Framework - Wx

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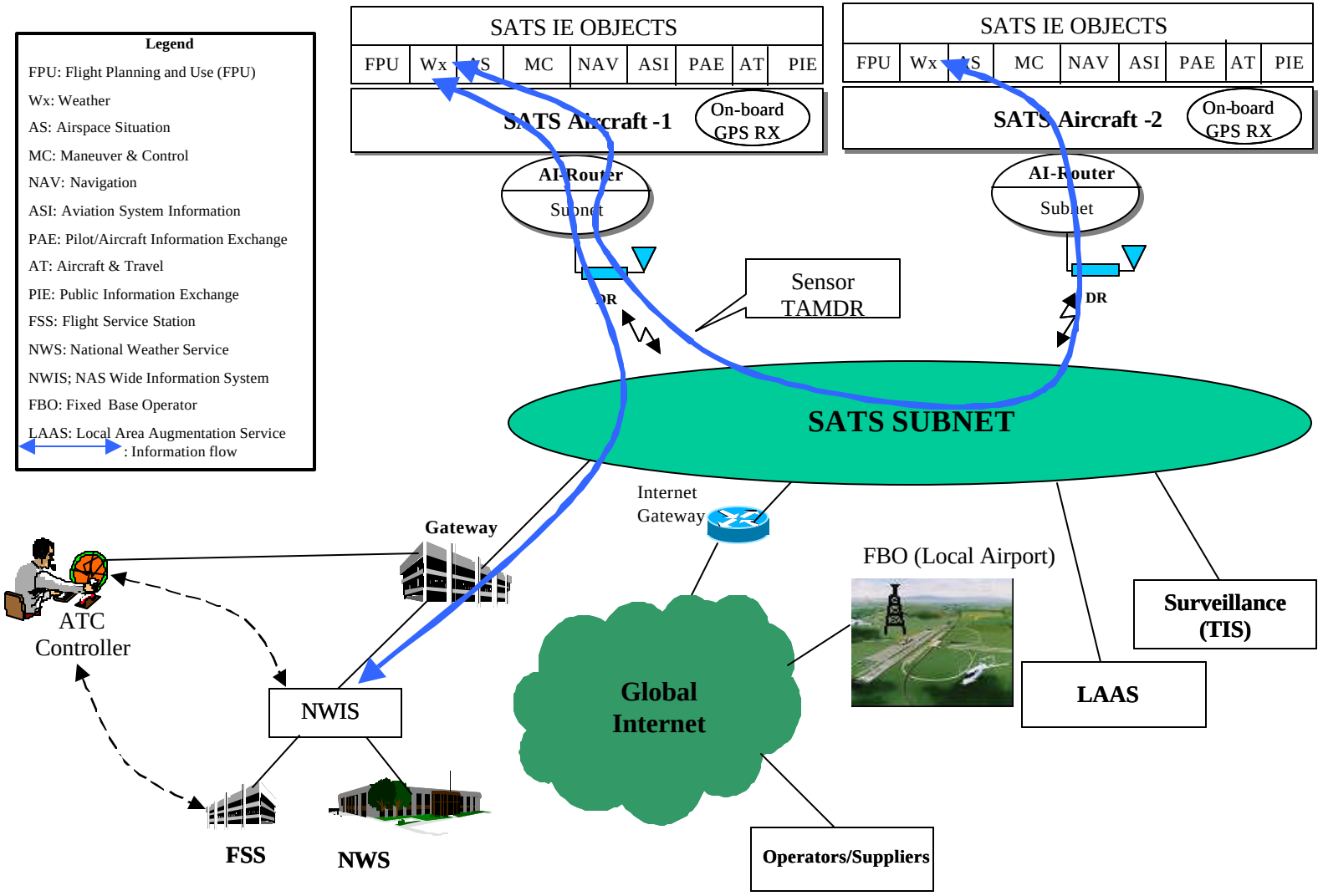

SATS AI Architectures

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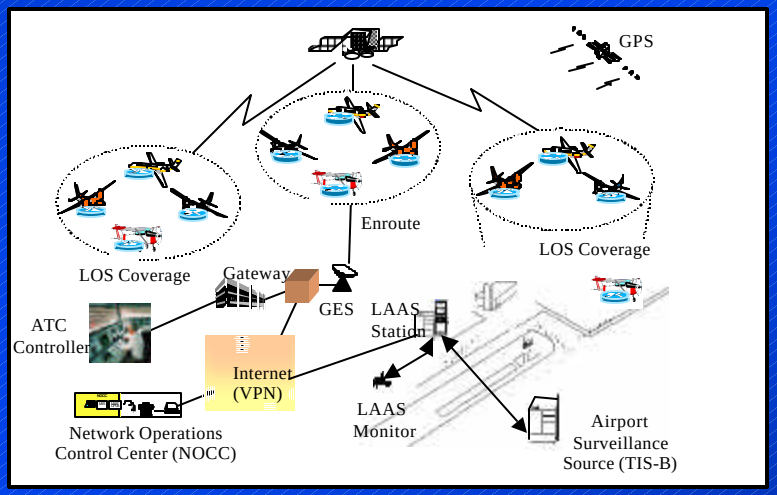
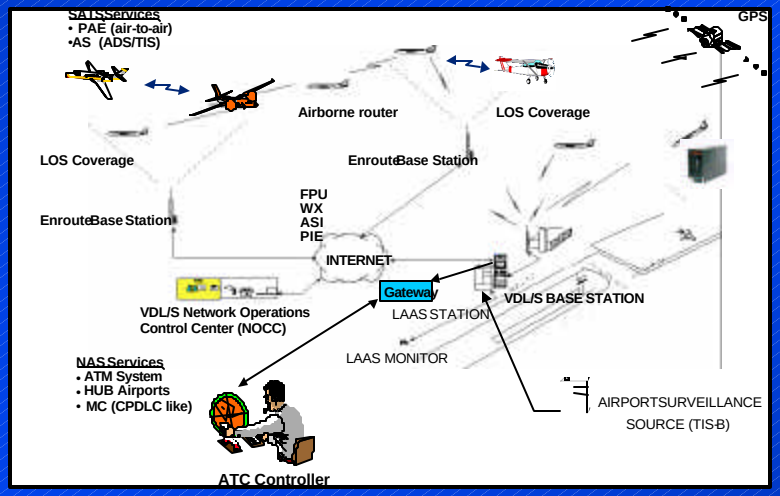
Architecture Principles

Ref	Principle
1	Provides the means to fully support the functional services.
2	The AI will be separable into platform specific systems defined as the CMS and a system defined NMS. To this extent the architecture will modular.
3	The mechanisms and techniques employed with the AI will be self-organizing.
4	All communication, to the extent practical, will be performed through a primary means of communication.
5	Within the AI there will be no single point of failure.
6	The system will be constructed using open system standards.
7	The interface to the NAS (enroute, terminal controllers) will be through a gateway facility.
8	Provide for interfaces to the entities shown in the Entity relationship Model.
9	Provide for information and operational security.

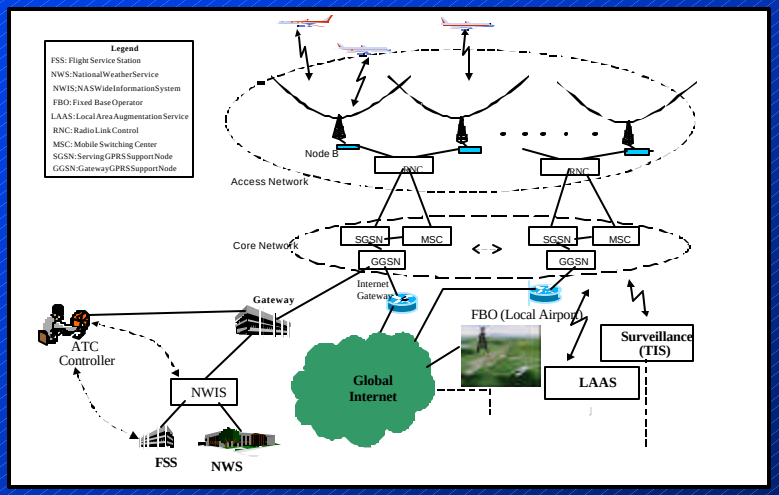
Space Centric Architecture



Air Centric Architecture



Ground Centric Architecture



Evaluation Factors and Architecture Models

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Evaluation Factors

- Cost
  - On-board and off-board cost components
  - Infrastructure requirements
  - Overlay on existing or new infrastructure to support SATS AI
  - SATS dedicated infrastructure or shared (and paid for) by other users
  - Use of airport area as cost model
- Availability
  - Time horizon
- Performance
  - Adherence to AI architectural principles
  - Functional requirements
  - Bandwidth sizing
  - Reliability – redundancy
  - Delay
- Scalability
- Risk Assessment

Candidate Architectures for Comparison

Technology	Space	Air	Ground
Inmarsat INM 3 & 4	√		
VDL Mode SATS		√	
UMTS for ATC			√
3 GPP			√
TCP/IP, Mobile IP, Multicast	√	√	√
TIS-B, LAAS	√	√	√
Peer-to-Peer	√	√	√
Self Organizing (Manet)		√	
CDMA			√
IPSec	√	√	√

AI Architectural Evaluation Results

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- **Aircraft Centric Architecture**
  - **Meets SATS requirements**
  - **Low risk, low cost, near COTS option**
  - **ICAO standards based with multiple hardware vendors**
- **Space Centric Architecture**
  - **Available as a service now**
  - **Existing aircraft can be upgraded to this service**
  - **Transition higher bandwidth with Inmarsat-4 constellation**
- **Ground Centric Architecture**
  - **UMTS technology has no inherent show stoppers and meets SATS requirements**
  - **High risk - dependence on commercial aviation for development, certification and deployment of technology**

Aircraft - centric currently evaluated as best approach.

Test Bed – Build A with Mode SATS

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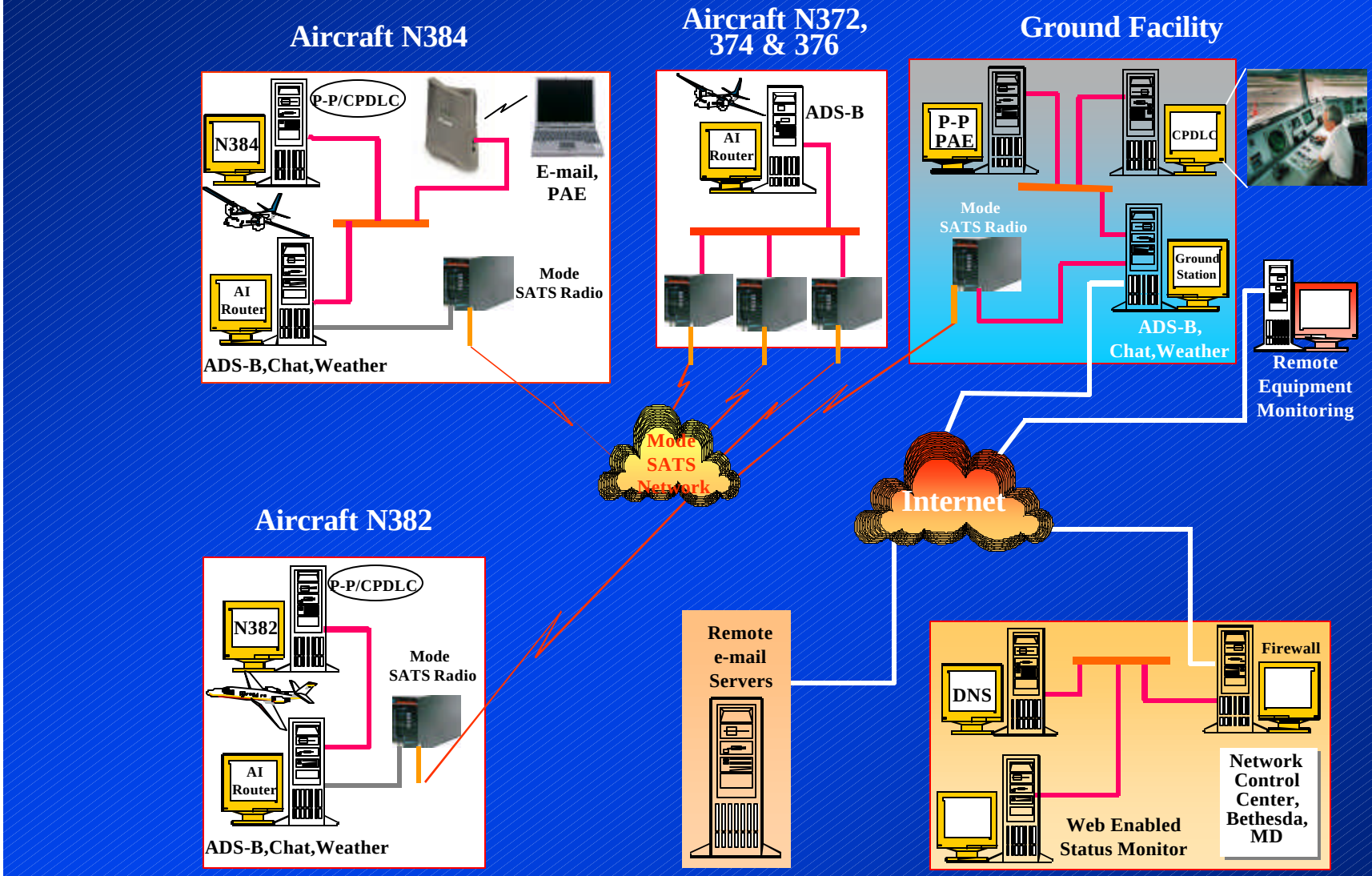

SATS Nodal Protocol Architecture

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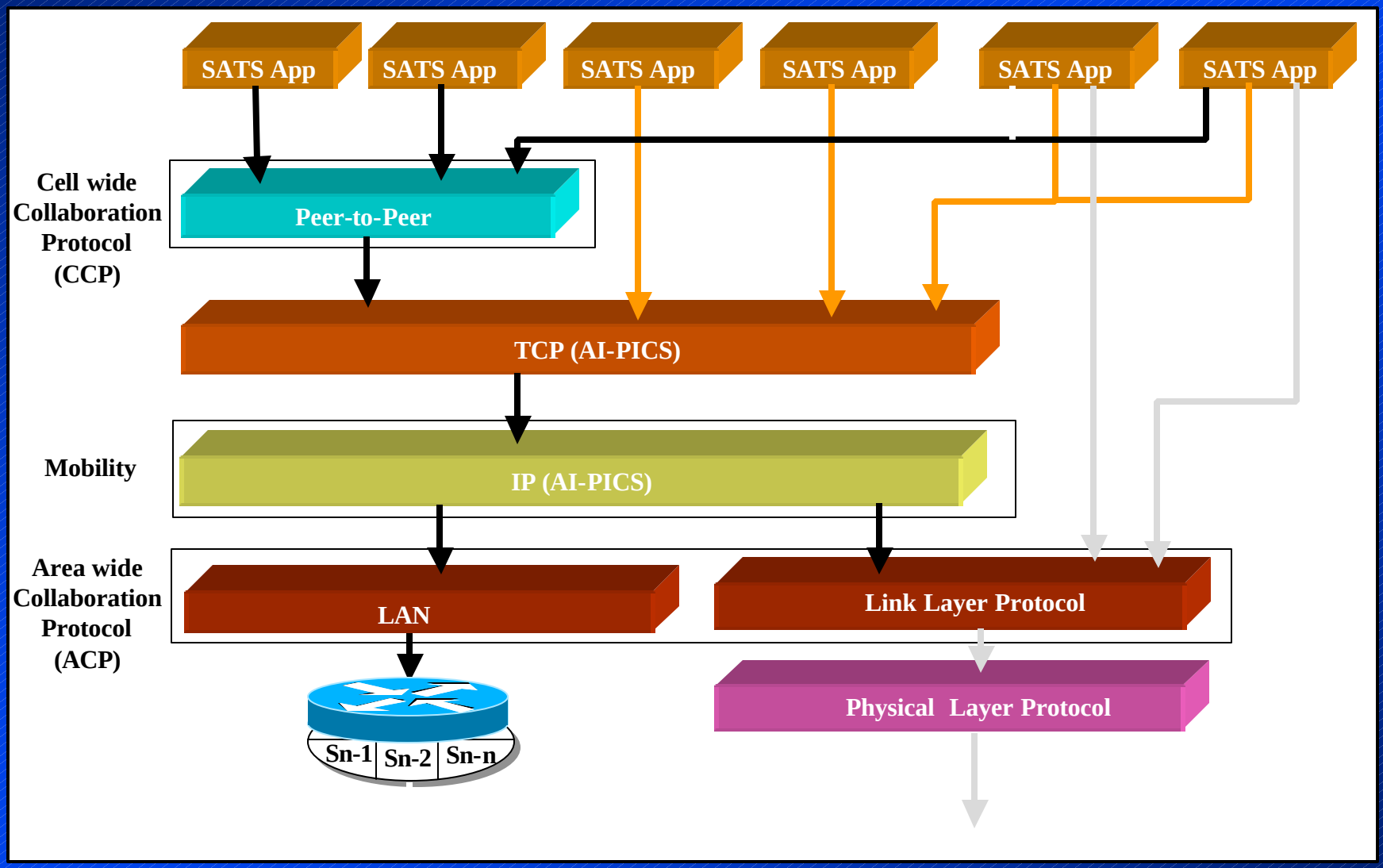

Airborne Internet Build A Features

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- VDL Mode SATS point-to-point and broadcast communication capability:
  - Air-to-air, self organizing, peer-to-peer communication
  - Functionality/interoperability
- Demonstrated "all-in-one" AI connectivity.
- Internet connectivity.
- Integrated hardware/software components from many suppliers.
- Successfully implemented and tested the software based router for SATS AI.

Integrated Components
Mode SATS VHF Radio
EFR 300 Ground Station
VDL Mode Subnet Emulation using RF Attenuator
ADS-B Position Reporting System
FIS-B Graphical Weather Products
ATN CPDLC
Pilot/Aircraft Information Exchange
Netscape
E-mail Application
Web-enabled Remote Equipment Status Monitor
Aircraft Mobility Based on DNS
Peer to Peer tool
Intel-based Workstations and Sun Workstations (Ultra 10)

Configuration and integration work represents a "one of a kind" rapid prototype of the airborne internet.

Current Status

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- **Sustaining Testbed Build A**

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